US009094598B2

(12) **United States Patent**
Sakurai

(10) **Patent No.: US 9,094,598 B2**
(45) **Date of Patent: Jul. 28, 2015**

(54) **IMAGE PICKUP APPARATUS AND FOCUSING METHOD WITH FIRST AND SECOND IMAGE PICKUPS ON PRIMARY AND SECONDARY IMAGING PLANES**

(75) Inventor: **Hiroshi Sakurai**, Chiba (JP)

(73) Assignee: **CANON KABUSHIKI KAISHA**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 110 days.

(21) Appl. No.: **13/095,000**

(22) Filed: **Apr. 27, 2011**

(65) **Prior Publication Data**

US 2011/0267532 A1 Nov. 3, 2011

(30) **Foreign Application Priority Data**

Apr. 30, 2010 (JP) 2010-105596

(51) **Int. Cl.**
H04N 5/232 (2006.01)
H04N 5/369 (2011.01)

(52) **U.S. Cl.**
CPC ***H04N 5/23212*** (2013.01); ***H04N 5/3696*** (2013.01)

(58) **Field of Classification Search**
CPC H04N 5/232; H04N 5/23293; H04N 5/23212; H04N 5/23219; H04N 5/3696
USPC 348/208.12, 346, 345
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0189662 A1* 10/2003 Matsuda 348/345
2006/0165403 A1* 7/2006 Ito 396/123
2006/0262659 A1* 11/2006 Kurosawa 369/1
2007/0206937 A1* 9/2007 Kusaka 396/89
2008/0267601 A1* 10/2008 Kobayashi 396/91
2009/0110383 A1* 4/2009 Fujii 396/128
2010/0013947 A1* 1/2010 Oikawa 348/222.1
2011/0228127 A1* 9/2011 Nakagawa 348/222.1

FOREIGN PATENT DOCUMENTS

JP 2001-128044 5/2001
JP 2001-174690 6/2001
JP 2005-012307 1/2005
JP 2006-146031 A 6/2006
JP 2007-233032 A 9/2007
JP 2007-316496 A 12/2007
JP 2009244429 A * 10/2009
JP 2010-008602 A 1/2010

OTHER PUBLICATIONS

Jan. 7, 2014 Japanese Office Action, that issued in Japanese Patent Application No. 2010-105596.

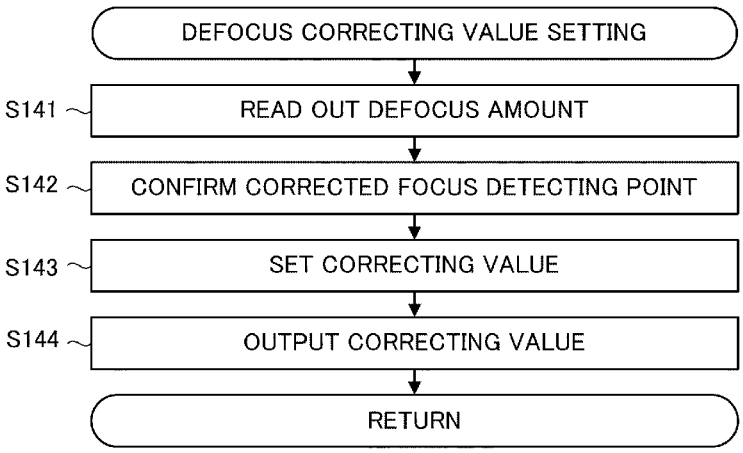
* cited by examiner

Primary Examiner — Nicholas Giles
Assistant Examiner — Abdelaaziz Tissire
(74) *Attorney, Agent, or Firm* — Cowan, Liebowitz & Latman, P.C.

(57) **ABSTRACT**

An image pickup apparatus includes an image pickup element that includes a plurality of image pickup pixels and a plurality of focus detecting pixels, a detector configured to detect a phase difference between two images of the object on a secondary imaging plane, and a controller configured to provide focusing based on a defocus amount obtained from a detection result of the detector for a first focus detecting point, and set a correcting value used to correct a defocus amount obtained from a next detection result of the detector so that a difference can reduce between the defocus amount obtained from the detection result of the detector for the first focus detecting point and a defocus amount obtained from the focus detecting pixels for the first focus detecting point of a captured image of the object that has been captured.

7 Claims, 12 Drawing Sheets



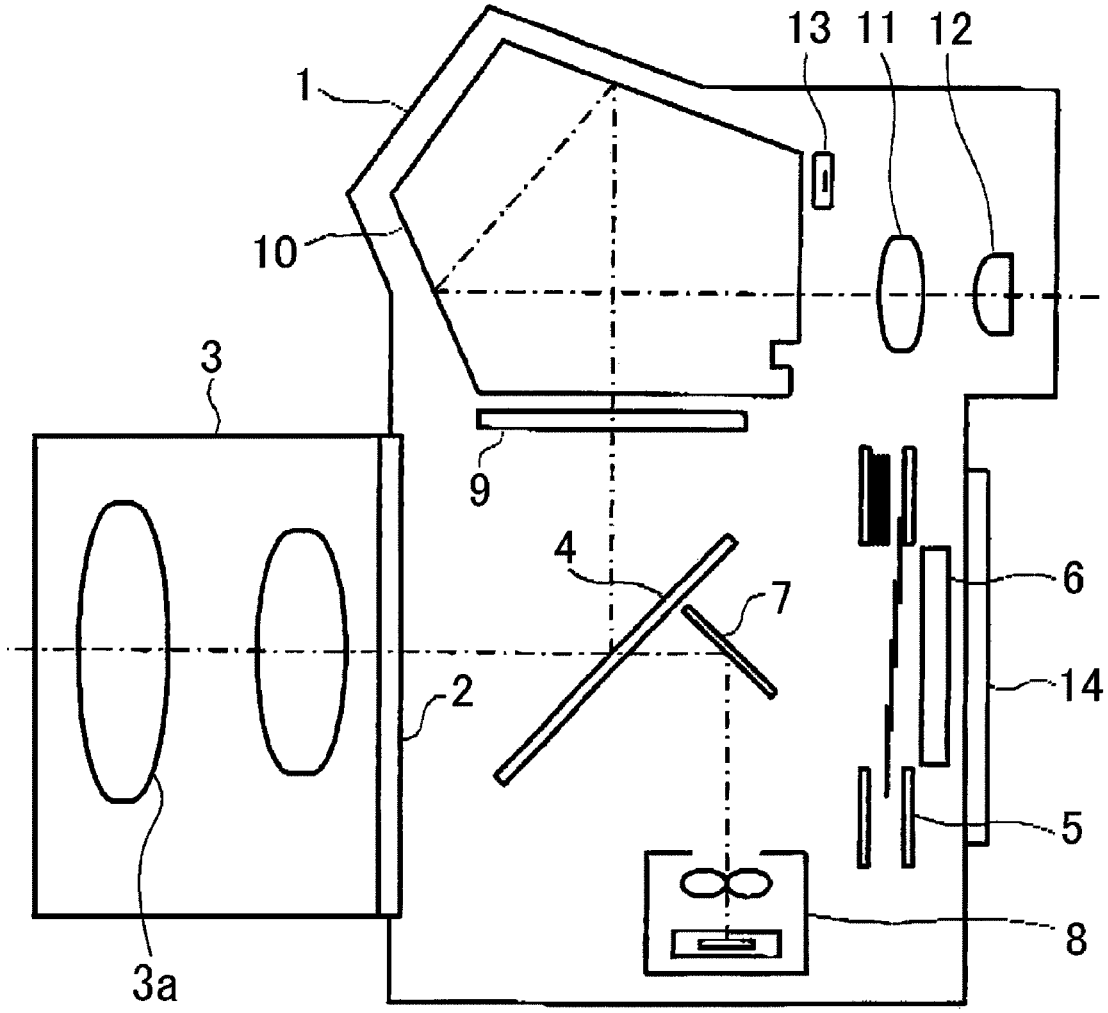


FIG. 1

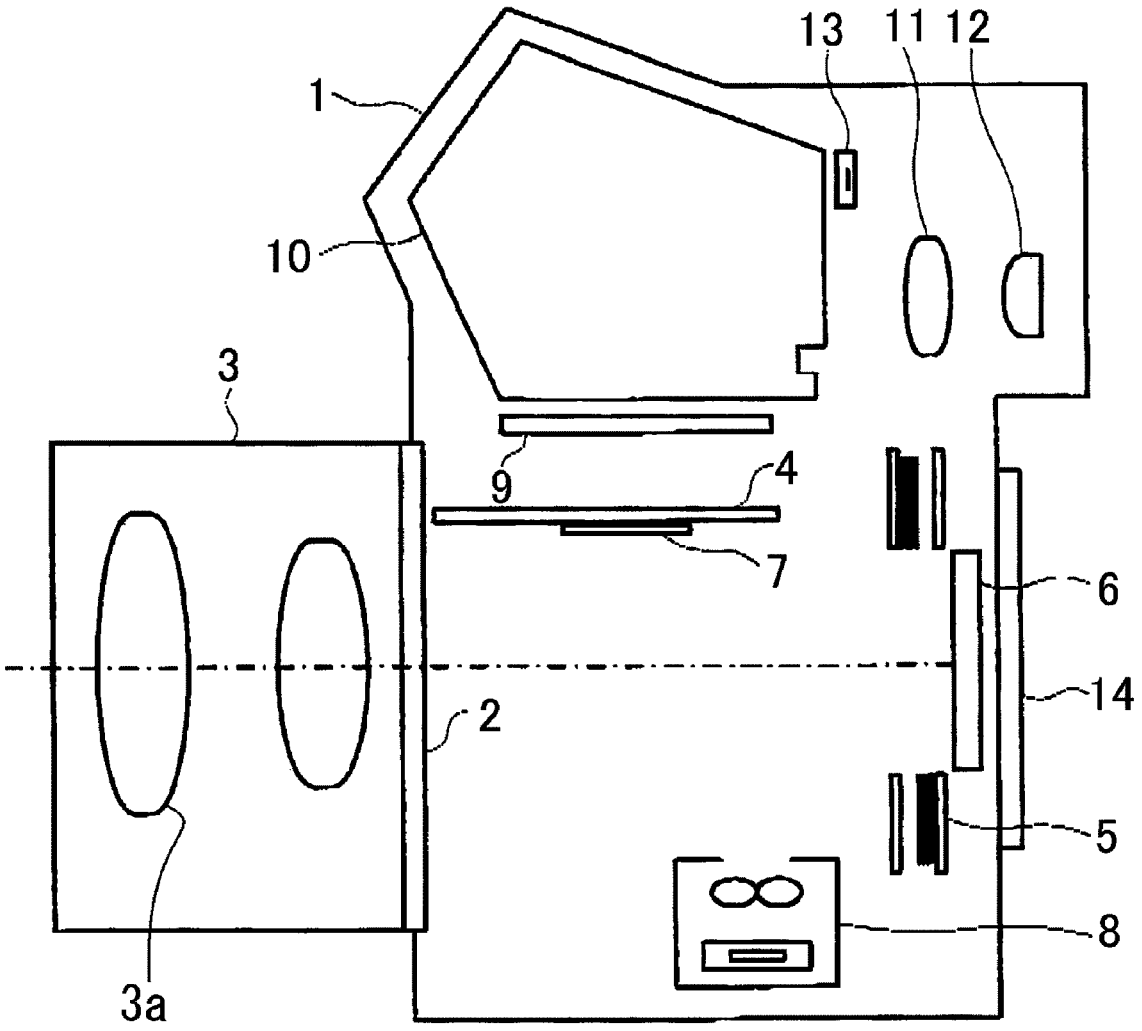


FIG. 2

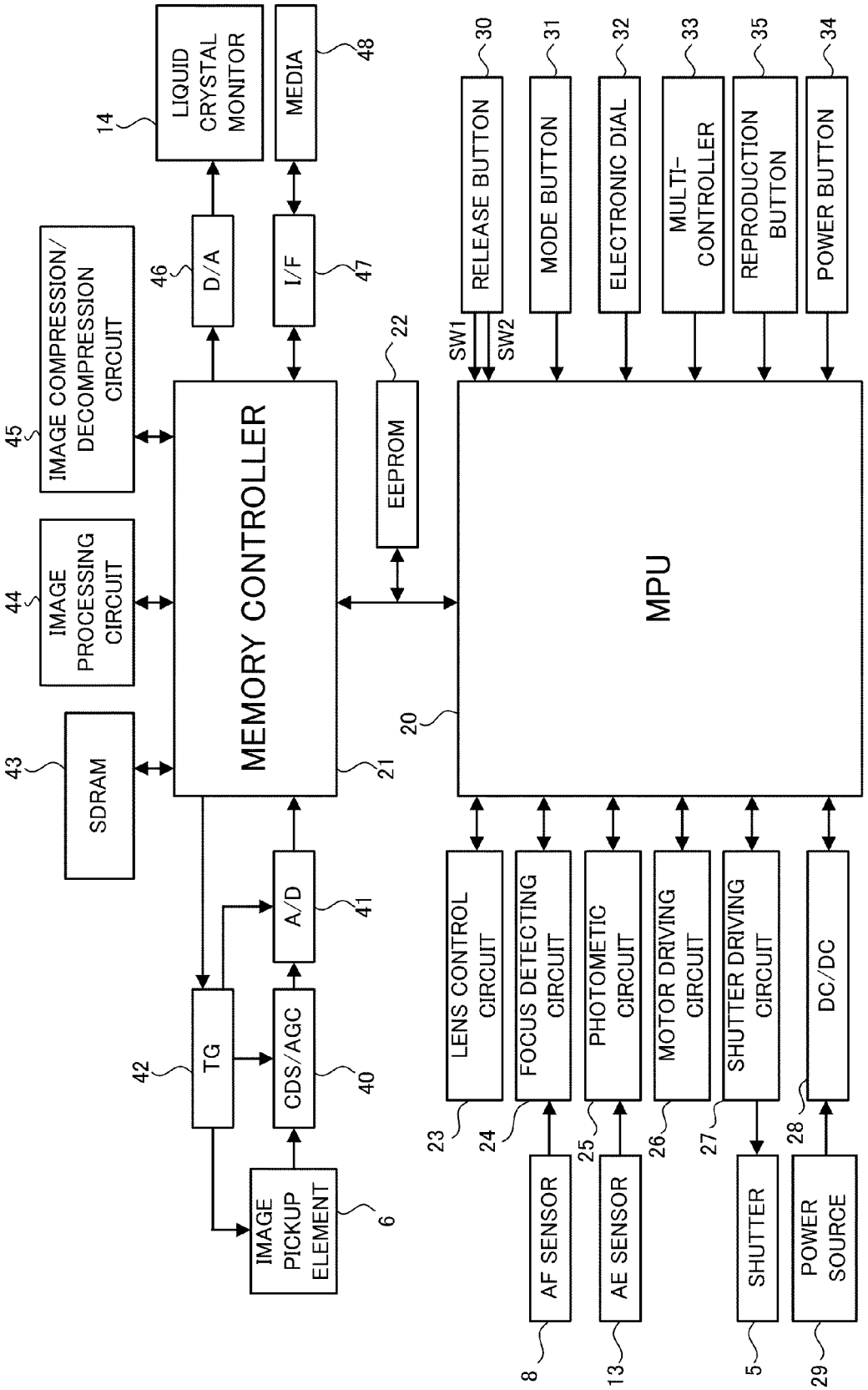

LIQUID CRYSTAL MONITOR
14
MEDIA
48
D/A
46
I/F
47
IMAGE COMPRESSION/ DECOMPRESSION CIRCUIT
45
IMAGE PROCESSING CIRCUIT
44
SDRAM
43
MEMORY CONTROLLER
21
EEPROM
22
MPU
20
RELEASE BUTTON
30
MODE BUTTON
31
ELECTRONIC DIAL
32
MULTI-CONTROLLER
33
REPRODUCTION BUTTON
35
POWER BUTTON
34
SW1
SW2
A/D
41
TG
42
CDS/AGC
40
IMAGE PICKUP ELEMENT
6
LENS CONTROL CIRCUIT
23
FOCUS DETECTING CIRCUIT
24
PHOTOMETIC CIRCUIT
25
MOTOR DRIVING CIRCUIT
26
SHUTTER DRIVING CIRCUIT
27
DC/DC
28
AF SENSOR
8
AE SENSOR
13
SHUTTER
5
POWER SOURCE
29

FIG. 3

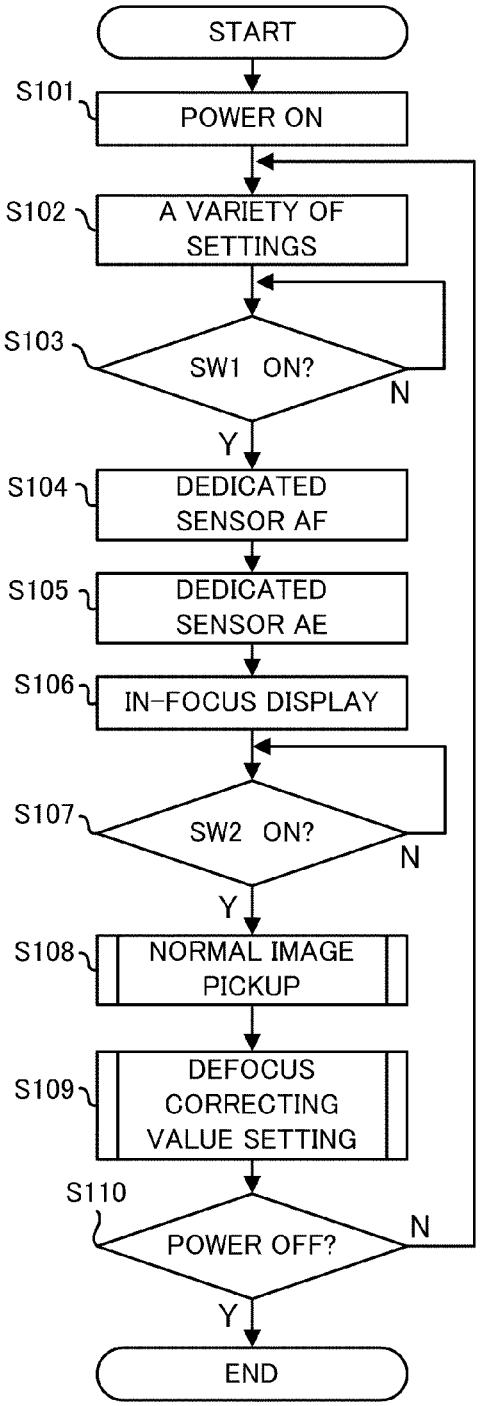

START
S101
POWER ON
S102
A VARIETY OF SETTINGS
S103
SW1 ON?
N
Y
S104
DEDICATED SENSOR AF
S105
DEDICATED SENSOR AE
S106
IN-FOCUS DISPLAY
S107
SW2 ON?
N
Y
S108
NORMAL IMAGE PICKUP
S109
DEFOCUS CORRECTING VALUE SETTING
S110
POWER OFF?
N
Y
END

FIG. 4

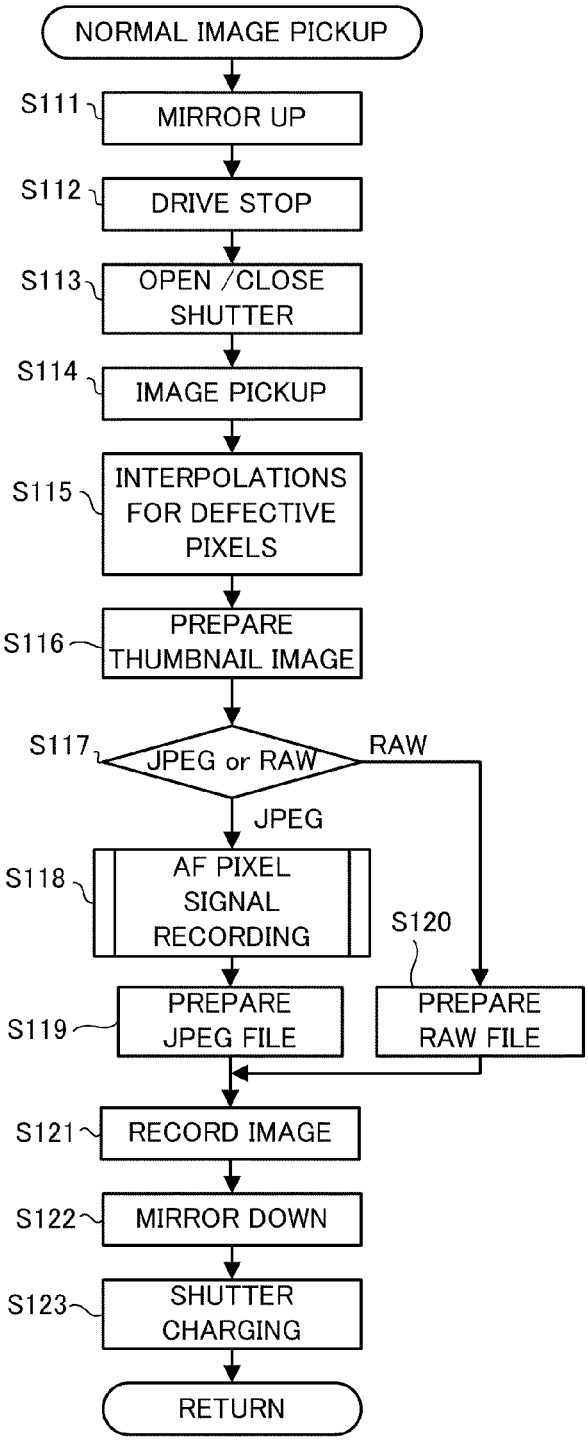

NORMAL IMAGE PICKUP
S111
MIRROR UP
S112
DRIVE STOP
S113
OPEN /CLOSE SHUTTER
S114
IMAGE PICKUP
S115
INTERPOLATIONS FOR DEFECTIVE PIXELS
S116
PREPARE THUMBNAIL IMAGE
S117
JPEG or RAW
RAW
JPEG
S118
AF PIXEL SIGNAL RECORDING
S120
S119
PREPARE JPEG FILE
PREPARE RAW FILE
S121
RECORD IMAGE
S122
MIRROR DOWN
S123
SHUTTER CHARGING
RETURN

FIG. 5

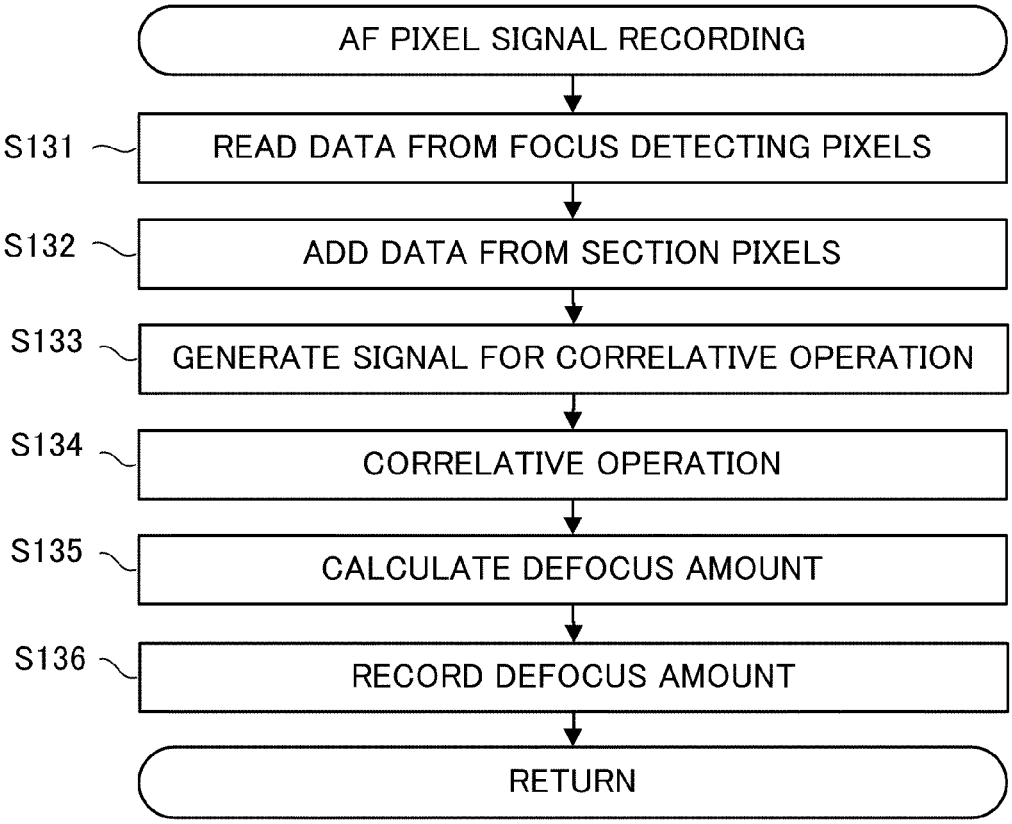

AF PIXEL SIGNAL RECORDING
S131
READ DATA FROM FOCUS DETECTING PIXELS
S132
ADD DATA FROM SECTION PIXELS
S133
GENERATE SIGNAL FOR CORRELATIVE OPERATION
S134
CORRELATIVE OPERATION
S135
CALCULATE DEFOCUS AMOUNT
S136
RECORD DEFOCUS AMOUNT
RETURN

FIG. 6

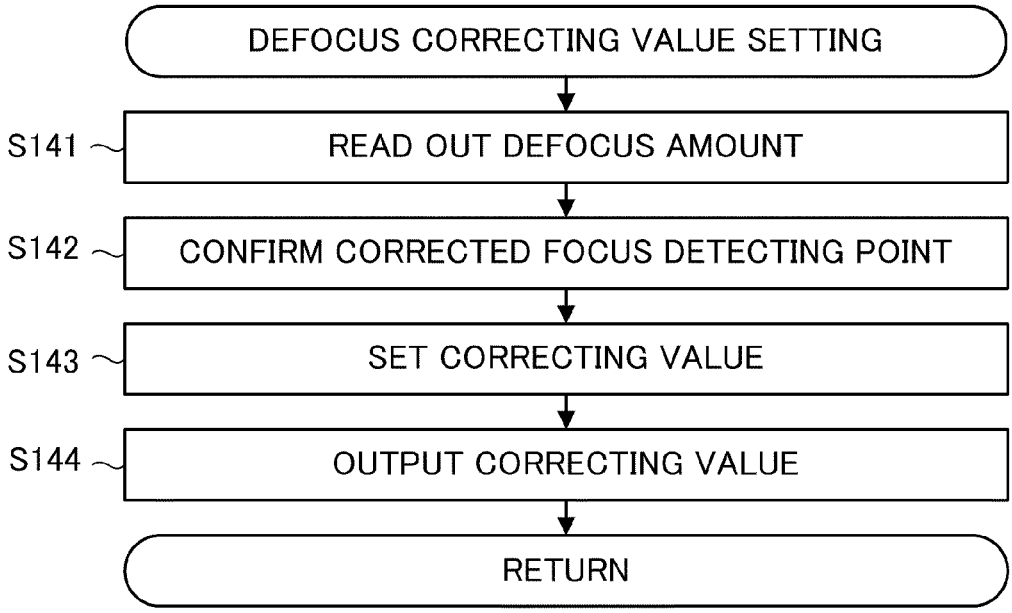

DEFOCUS CORRECTING VALUE SETTING
S141
READ OUT DEFOCUS AMOUNT
S142
CONFIRM CORRECTED FOCUS DETECTING POINT
S143
SET CORRECTING VALUE
S144
OUTPUT CORRECTING VALUE
RETURN

FIG. 7

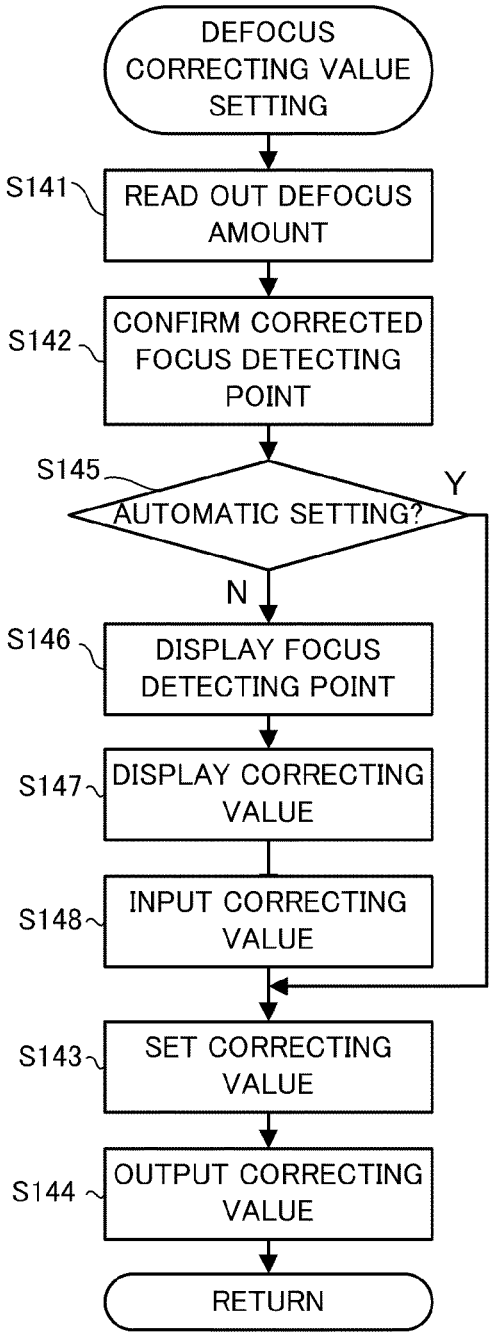

DEFOCUS CORRECTING VALUE SETTING
S141
READ OUT DEFOCUS AMOUNT
S142
CONFIRM CORRECTED FOCUS DETECTING POINT
S145
AUTOMATIC SETTING?
Y
N
S146
DISPLAY FOCUS DETECTING POINT
S147
DISPLAY CORRECTING VALUE
S148
INPUT CORRECTING VALUE
S143
SET CORRECTING VALUE
S144
OUTPUT CORRECTING VALUE
RETURN

FIG. 8

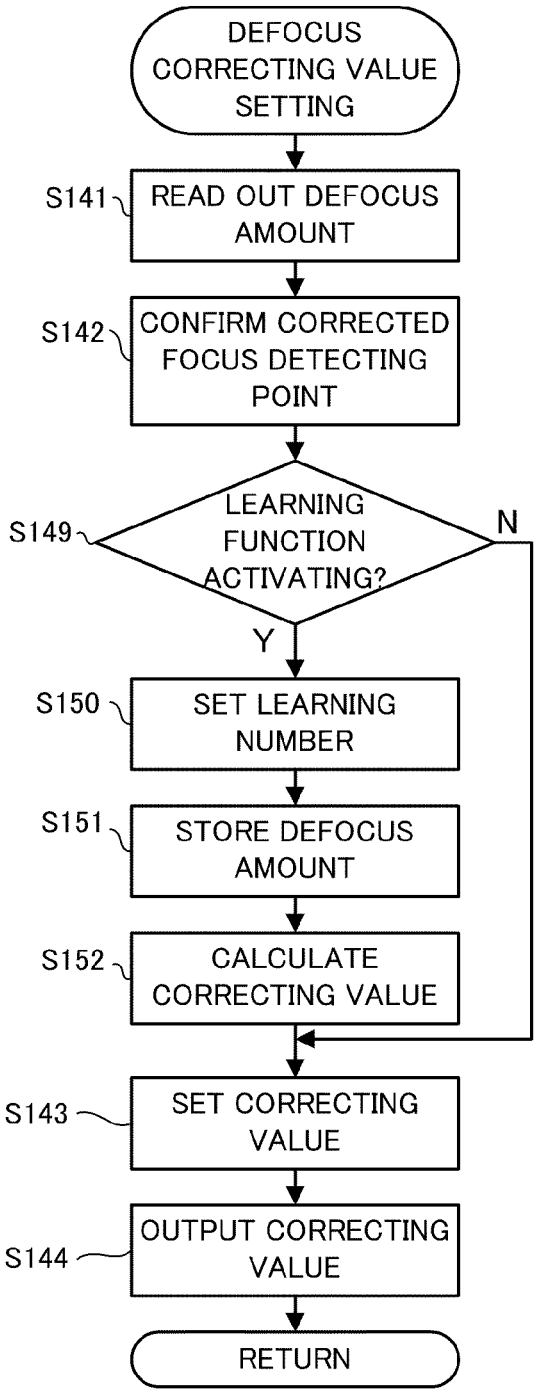

DEFOCUS CORRECTING VALUE SETTING
S141
READ OUT DEFOCUS AMOUNT
S142
CONFIRM CORRECTED FOCUS DETECTING POINT
S149
LEARNING FUNCTION ACTIVATING?
N
Y
S150
SET LEARNING NUMBER
S151
STORE DEFOCUS AMOUNT
S152
CALCULATE CORRECTING VALUE
S143
SET CORRECTING VALUE
S144
OUTPUT CORRECTING VALUE
RETURN

FIG. 9

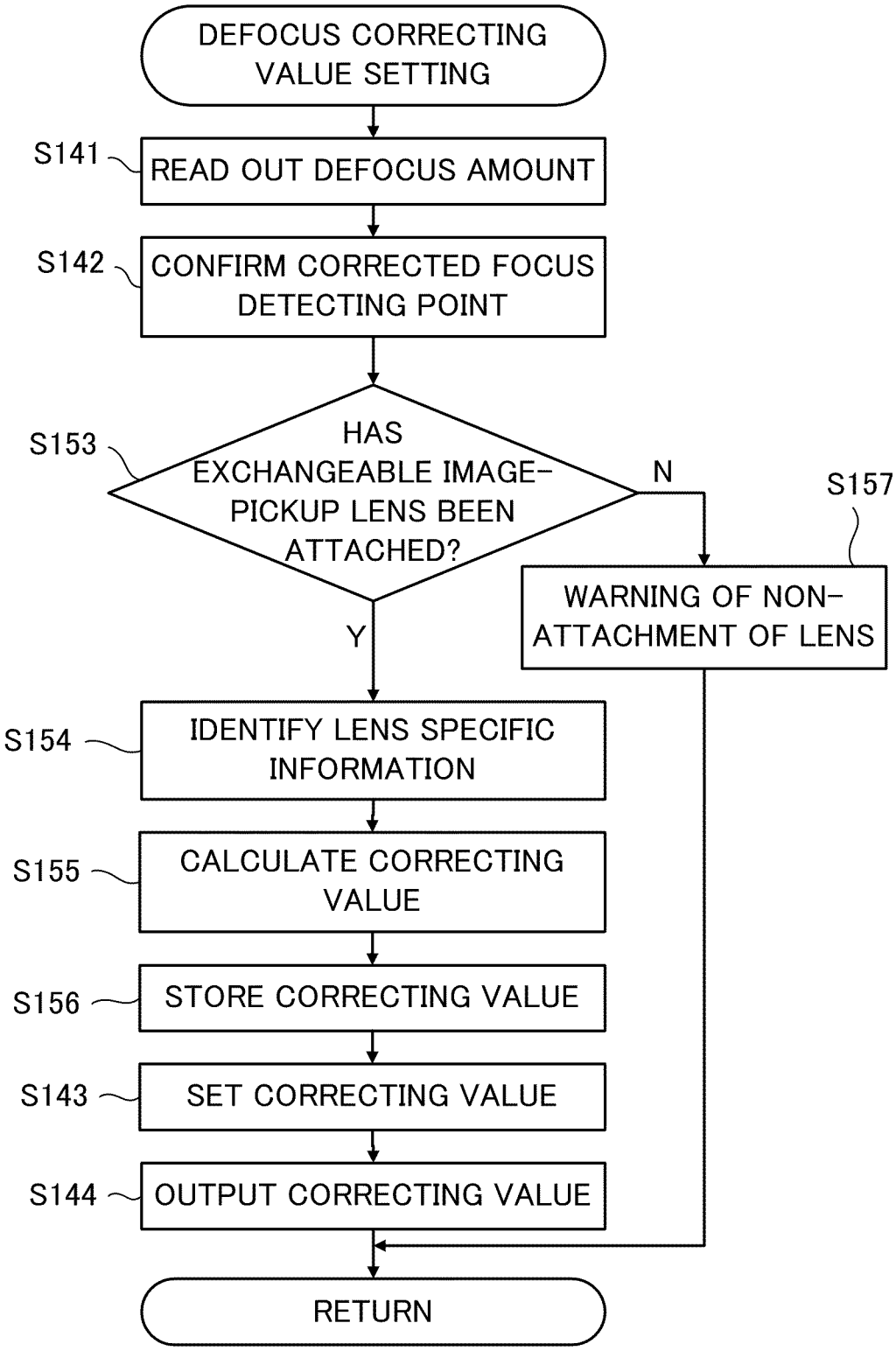

DEFOCUS CORRECTING VALUE SETTING
S141
READ OUT DEFOCUS AMOUNT
S142
CONFIRM CORRECTED FOCUS DETECTING POINT
S153
HAS EXCHANGEABLE IMAGE-PICKUP LENS BEEN ATTACHED?
N
S157
WARNING OF NON-ATTACHMENT OF LENS
Y
S154
IDENTIFY LENS SPECIFIC INFORMATION
S155
CALCULATE CORRECTING VALUE
S156
STORE CORRECTING VALUE
S143
SET CORRECTING VALUE
S144
OUTPUT CORRECTING VALUE
RETURN

FIG. 10

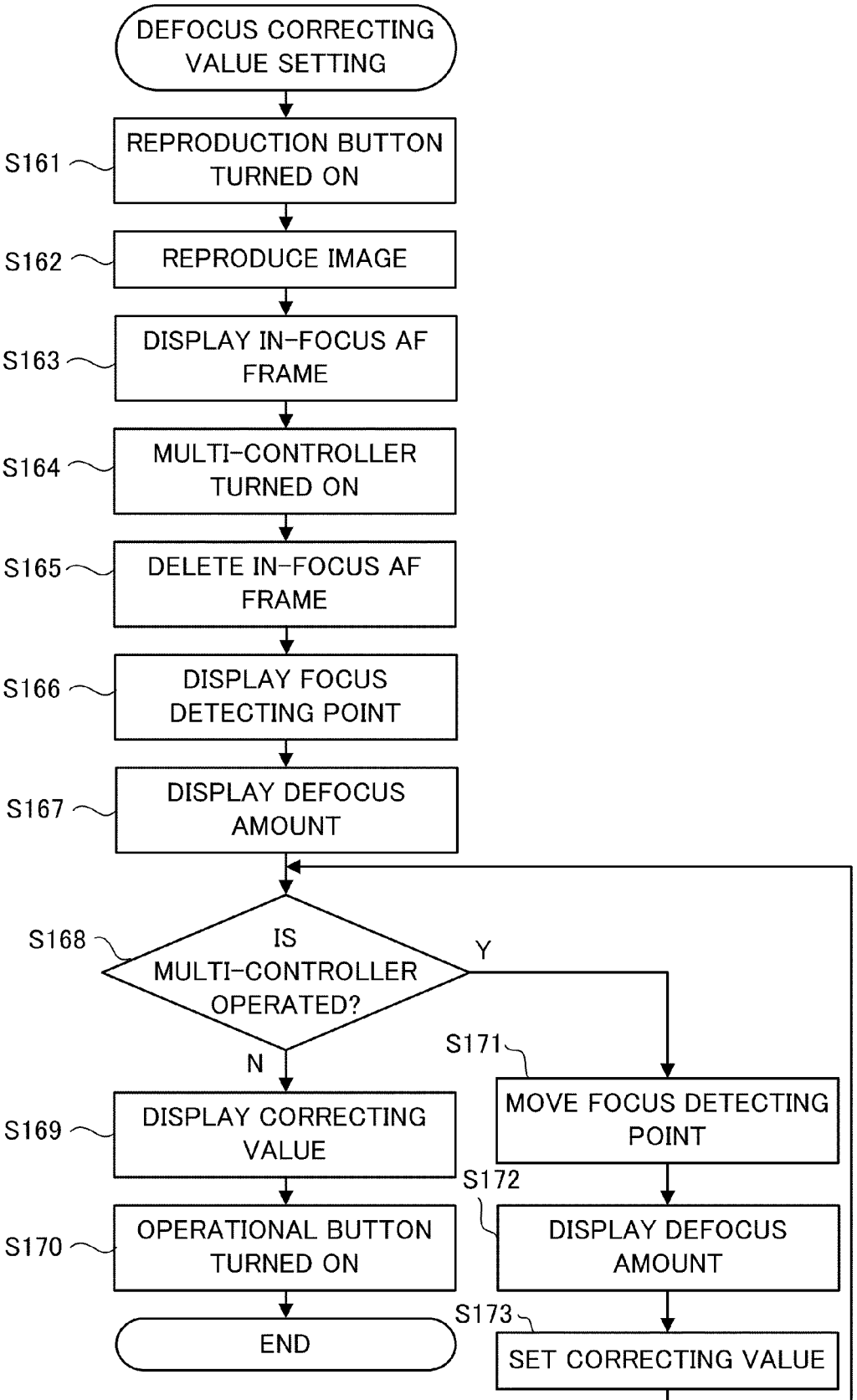

DEFOCUS CORRECTING VALUE SETTING
S161
REPRODUCTION BUTTON TURNED ON
S162
REPRODUCE IMAGE
S163
DISPLAY IN-FOCUS AF FRAME
S164
MULTI-CONTROLLER TURNED ON
S165
DELETE IN-FOCUS AF FRAME
S166
DISPLAY FOCUS DETECTING POINT
S167
DISPLAY DEFOCUS AMOUNT
S168
IS MULTI-CONTROLLER OPERATED?
Y
N
S171
MOVE FOCUS DETECTING POINT
S172
DISPLAY DEFOCUS AMOUNT
S173
SET CORRECTING VALUE
S169
DISPLAY CORRECTING VALUE
S170
OPERATIONAL BUTTON TURNED ON
END

FIG. 11

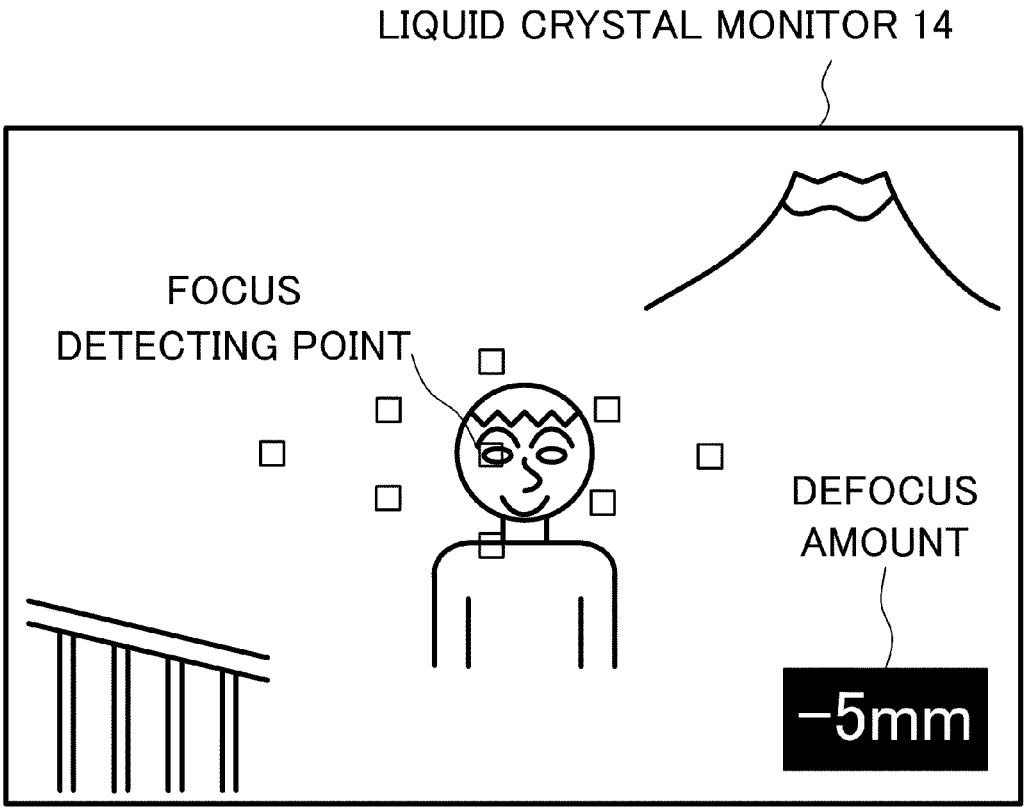

LIQUID CRYSTAL MONITOR 14
FOCUS
DETECTING POINT
DEFOCUS
AMOUNT
-5mm

FIG. 12

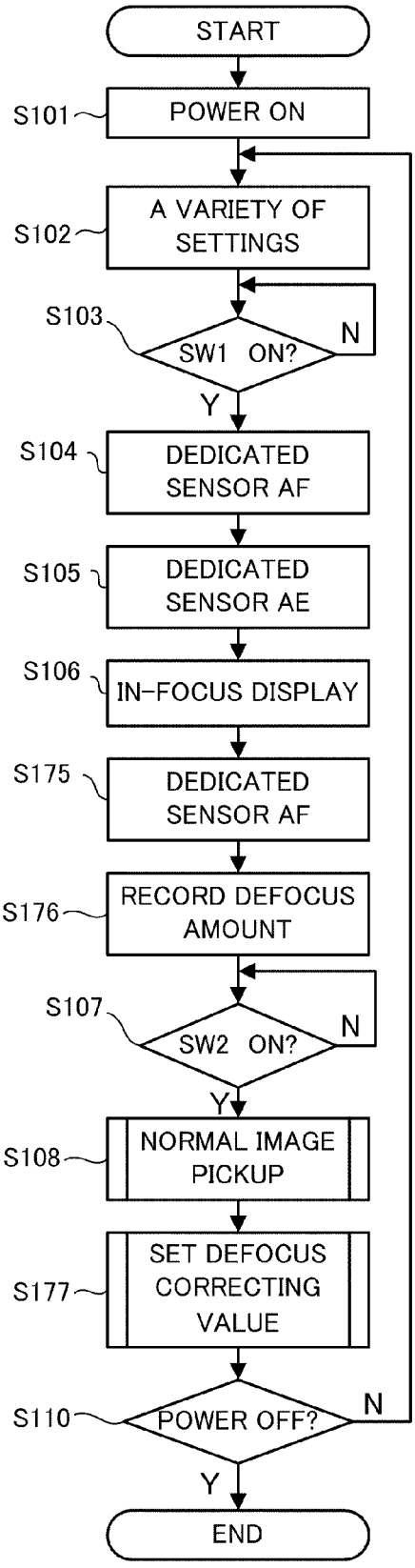

START
S101
POWER ON
S102
A VARIETY OF SETTINGS
S103
SW1 ON?
N
Y
S104
DEDICATED SENSOR AF
S105
DEDICATED SENSOR AE
S106
IN-FOCUS DISPLAY
S175
DEDICATED SENSOR AF
S176
RECORD DEFOCUS AMOUNT
S107
SW2 ON?
N
Y
S108
NORMAL IMAGE PICKUP
S177
SET DEFOCUS CORRECTING VALUE
S110
POWER OFF?
N
Y
END

FIG. 13

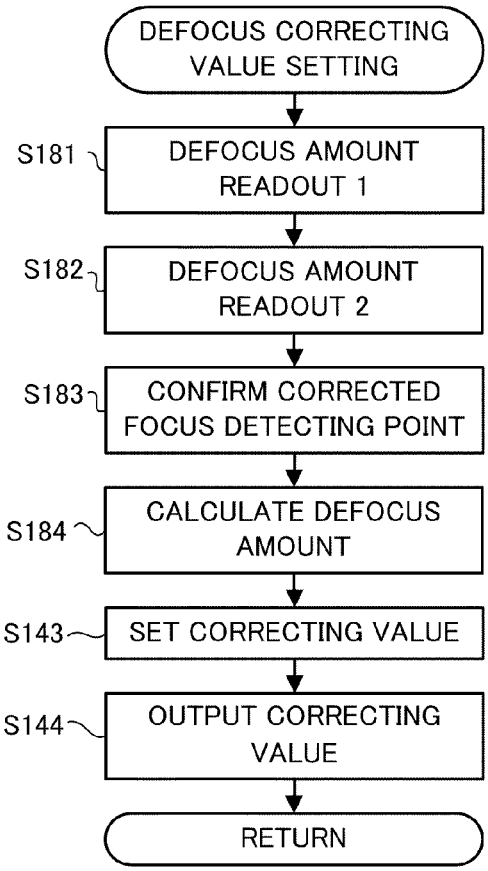

DEFOCUS CORRECTING VALUE SETTING
S181
DEFOCUS AMOUNT READOUT 1
S182
DEFOCUS AMOUNT READOUT 2
S183
CONFIRM CORRECTED FOCUS DETECTING POINT
S184
CALCULATE DEFOCUS AMOUNT
S143
SET CORRECTING VALUE
S144
OUTPUT CORRECTING VALUE
RETURN

FIG. 14

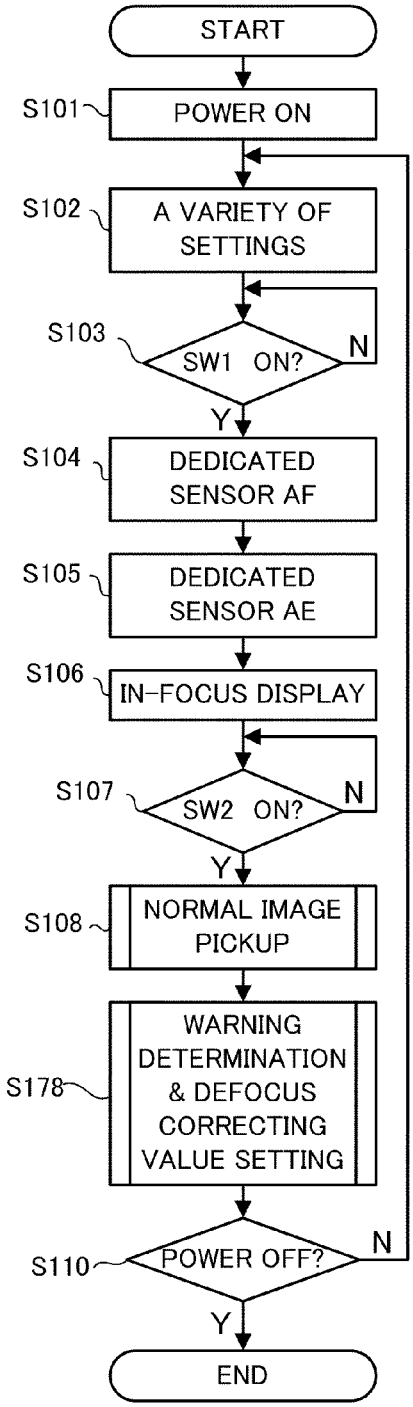

START
S101
POWER ON
S102
A VARIETY OF SETTINGS
S103
SW1 ON?
N
Y
S104
DEDICATED SENSOR AF
S105
DEDICATED SENSOR AE
S106
IN-FOCUS DISPLAY
S107
SW2 ON?
N
Y
S108
NORMAL IMAGE PICKUP
S178
WARNING DETERMINATION & DEFOCUS CORRECTING VALUE SETTING
S110
POWER OFF?
N
Y
END

FIG. 15

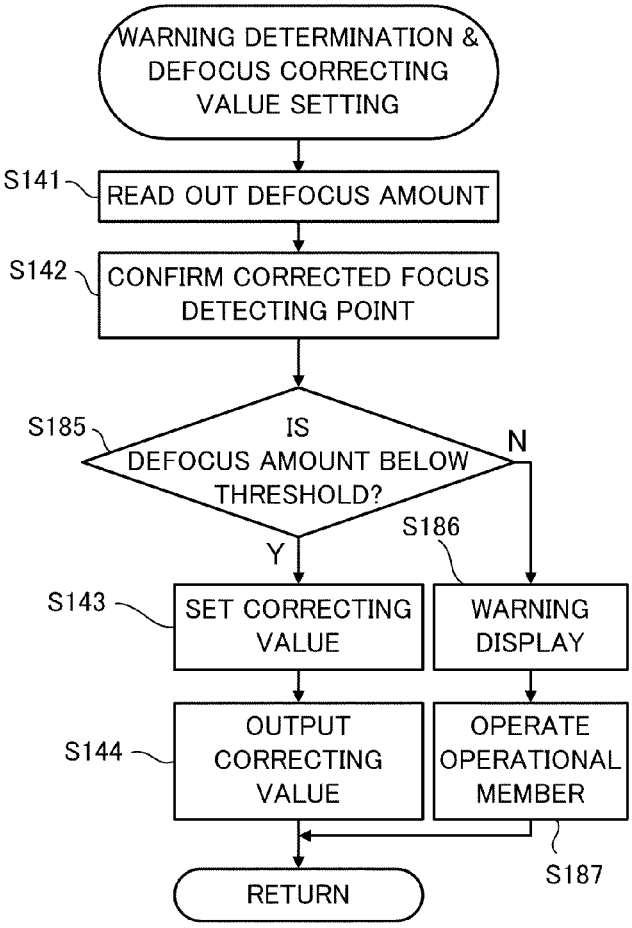

WARNING DETERMINATION & DEFOCUS CORRECTING VALUE SETTING
S141
READ OUT DEFOCUS AMOUNT
S142
CONFIRM CORRECTED FOCUS DETECTING POINT
S185
IS DEFOCUS AMOUNT BELOW THRESHOLD?
N
Y
S186
S143
SET CORRECTING VALUE
WARNING DISPLAY
S144
OUTPUT CORRECTING VALUE
OPERATE OPERATIONAL MEMBER
S187
RETURN

FIG. 16

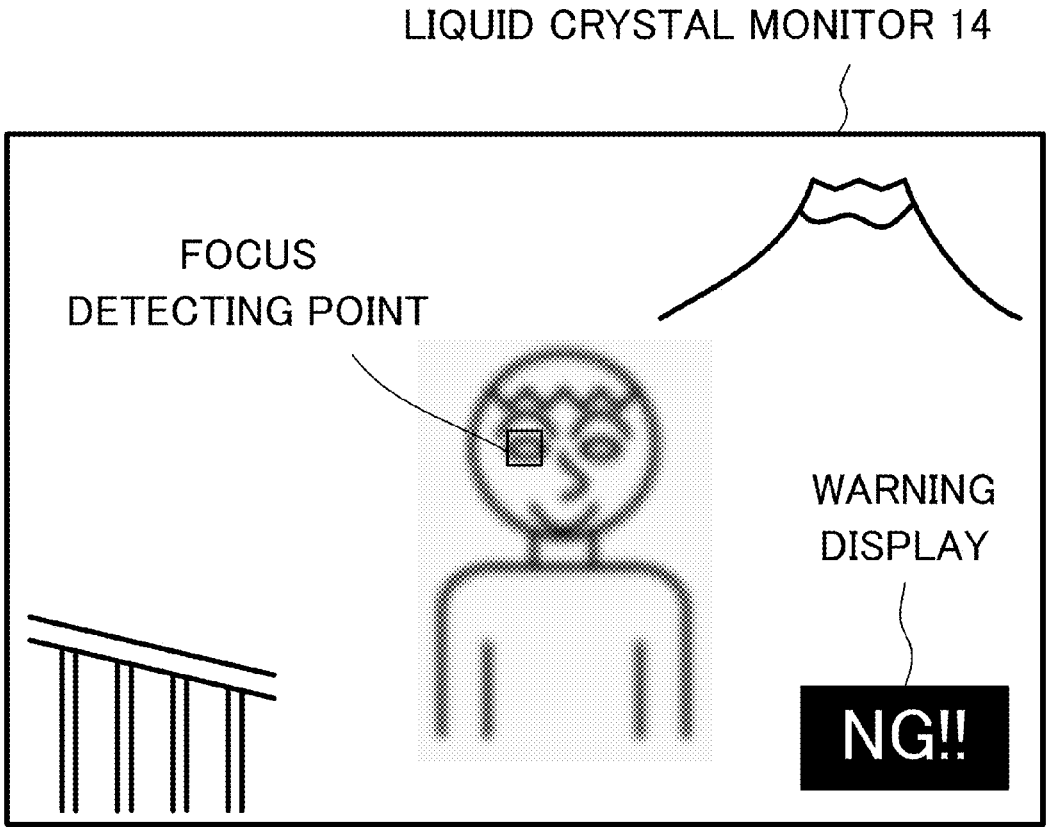

LIQUID CRYSTAL MONITOR 14
FOCUS
DETECTING POINT
WARNING
DISPLAY
NG!!

FIG. 17

IMAGE PICKUP APPARATUS AND FOCUSING METHOD WITH FIRST AND SECOND IMAGE PICKUPS ON PRIMARY AND SECONDARY IMAGING PLANES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an image pickup apparatus and a focusing method.

2. Description of the Related Art

A phase difference detecting method is known as an auto-focusing ("AF") method. Japanese Patent Laid-Open No. ("JP") 2009-244429 proposes an image pickup apparatus that includes an image pickup element that has focus detecting pixels and is configured to provide a phase difference AF on an image pickup plane, and a dedicated sensor that provides a phase difference AF on a secondary imaging plane. Other prior art include JP 2001-174690, 2001-128044, and 2005-12307.

Since focus detecting data from the dedicated sensor represents the just previous state of the image pickup, the focus detecting data generated by the dedicated sensor at the focus detecting time does not correspond to a captured image when an object is a moving body, due to a time lag from the focus detection to image pickup. As a result, the in-focus precision deteriorates. Although there are conventionally demands for the improved in-focus precision in the phase difference AF using the dedicated sensor, none of prior art propose effective means for improving the in-focus precision using the dedicated sensor.

SUMMARY OF THE INVENTION

The present invention provides an image pickup apparatus and focusing method which can improve the in-focus precision using a dedicated sensor.

An image pickup apparatus according to the present invention includes an image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, and a plurality of focus detecting pixels each configured to receive light that passes part of an exit pupil of the image pickup lens, a detector configured to detect a phase difference between two images of the object on a secondary imaging plane, and a controller configured to provide focusing based on a defocus amount obtained from a detection result of the detector for a first focus detecting point, and set a correcting value used to correct a defocus amount obtained from a next detection result of the detector so that a difference can be reduced between the defocus amount obtained from the detection result of the detector for the first focus detecting point and a defocus amount obtained from the focus detecting pixels for the first focus detecting point of a captured image of the object that has been captured.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a sectional view of a digital single-lens reflex camera of this embodiment.

FIG. **2** is a sectional view of the digital single-lens reflex camera in a state different from that illustrated in FIG. **1**.

FIG. **3** is a block diagram of a control system of the digital single-lens reflex camera illustrated in FIG. **1**.

FIG. **4** is a flowchart for explaining an operation of the digital single-lens reflex camera illustrated in FIG. **1**.

FIG. **5** is a flowchart for explaining a normal image pickup routine illustrated in FIG. **4**.

FIG. **6** is a flowchart for explaining a signal recording routine from focus detecting pixels illustrated in FIG. **5**.

FIG. **7** is a flowchart for explaining a defocus correcting value setting routine illustrated in FIG. **4** according to a first embodiment.

FIG. **8** is a flowchart for explaining a defocus correcting value setting routine illustrated in FIG. **4** according to a second embodiment.

FIG. **9** is a flowchart for explaining a defocus correcting value setting routine illustrated in FIG. **4** according to a third embodiment.

FIG. **10** is a flowchart for explaining a defocus correcting value setting routine illustrated in FIG. **4** according to a fourth embodiment.

FIG. **11** is a flowchart for explaining a defocus correcting value setting routine illustrated in FIG. **4** according to a fifth embodiment.

FIG. **12** is a diagram of a liquid crystal monitor illustrating a state of S**167** illustrated in FIG. **11**.

FIG. **13** is a flowchart for explaining an operation of a digital single-lens reflex camera according to a sixth embodiment.

FIG. **14** is a flowchart for explaining a defocus correcting value setting routine of S**177** illustrated in FIG. **13**.

FIG. **15** is a flowchart for explaining an operation of a digital single-lens reflex camera according to a seventh embodiment.

FIG. **16** is a flowchart for explaining a warning determining routine of S**178** illustrated in FIG. **15**.

FIG. **17** is a diagram of a liquid crystal monitor illustrating a warning display of S**186** illustrated in FIG. **16**.

DESCRIPTION OF THE EMBODIMENTS

FIGS. **1** and **2** are sectional views of a digital single-lens reflex camera (image pickup apparatus) of this embodiment. The image pickup apparatus of this embodiment is not limited to the digital single-lens reflex camera.

Reference numeral **1** denotes a camera body, reference numeral **2** denotes a mount that enables an image pickup lens **3** to be removably attached to the camera body **1**, and includes an interface unit configured to transmit a variety of signals and supply driving power.

Reference numeral **3** denotes an exchangeable image pickup lens, which includes a focus lens unit, a zoom lens unit, and a stop unit (not illustrated). In FIGS. **1** and **2**, one lens conveniently represents each lens unit; for example, a focus lens **3***a* represents the focus lens unit. However, each complicated lens unit actually includes a plurality of lenses. FIGS. **1** and **2** do not intend to limit the focus lens **3***a* to a front lens of the image pickup lens **3**.

Reference numeral **4** is a main mirror including a half-mirror rotatable in accordance with an operational state of the camera. The main mirror **4** is inclined in the image pickup optical path when a viewfinder is used to observe an object, and deflects and guides a light flux from the image pickup lens **3** to a finder optical system, which will be described later (FIG. **1**). The main mirror **4** retreats from the image pickup optical system at the image pickup time or the live view time, and allows a light flux from the image pickup lens **3** to enter an image pickup element **6**, which will be described later.

Reference numeral **5** denotes a shutter configured to control the incidence of the light flux from the image pickup lens **3** on the image pickup element **6**, which will be described later. The shutter **5** is closed usually (FIG. **1**), and opened at the image pickup time or at the live view time (FIG. **2**).

Reference numeral **6** denotes an image pickup element including a CMOS image sensor and its peripheral circuit. The image pickup element **6** is configured so that all of its pixels can independently output a signal. In addition, parts of the pixels are focus detecting pixels that enable a focus detection of a phase difference detecting method (phase difference AF) on an image pickup plane. More specifically, the image pickup element **6** includes a plurality of image pickup pixels each of which is configured to generate an image of the object when receiving light from the entire region on the exit pupil of the image pickup lens **3** configured to generate an image of the object.

The image pickup lens **6** further includes a plurality of focus detecting pixels each of which is configured to receive light that passes part of the area of the exit pupil of the image pickup lens **3**. The plurality of focus detecting pixels as a whole can receive the light that passes the entire region of the exit pupil of the image pickup lens **3**.

The image pickup plane phase difference AF is similar to that disclosed in JP 2009-244429, and a detailed description thereof will be omitted. In this embodiment, a block is defined as a square area of 100 pixels including **10** column times **10** rows. A cluster is defined as an area of 2×2=4 blocks. A field is defined as an area of 5×5=25 clusters. A section is defined as an area of 1 block in the lateral direction and 10 blocks in the longitudinal direction, totally 10 blocks.

One focus detecting area includes a plurality of (e.g., 10 in this embodiment) sections in the lateral direction. In other words, one focus detecting area has an area of 100 columns times 100 rows equal to ten thousand pixels in this embodiment, which is the same as one field. One focus detecting area constitutes one focus detecting point.

Reference numeral **7** denotes a sub-mirror configured to rotate with the main mirror **4**. The sub-mirror **4** deflects and guides the light flux that has transmitted through the main mirror **4** to an AF sensor **8**, which will be described later (FIG. **1**) when the main mirror is inclined in the image pickup optical path. The sub-mirror **7** rotates with the main mirror **4** at the image pickup time and at the live view time, and retreats from the image pickup optical path (FIG. **2**). The sub-mirror **7** is not a half-mirror, and shields the light from the image pickup element **6**.

Reference numeral **8** denotes a dedicated sensor (AF sensor) that serves as a detector, and includes a secondary imaging lens and a plurality of photoelectric conversion elements, like a CCD or CMOS area sensor. The AF sensor **8** is configured to detect a phase difference (or an interval) between two images of the object on the secondary imaging plane and to detect a phase difference. The AF sensor **8** outputs a potential change of the object image formed on the photoelectric conversion element; the MPU **20** obtains a defocus amount based on the output and provides the AF.

Reference numeral **9** denotes a focus plate arranged on a primary imaging surface of the image pickup lens **3**, which includes a Fresnel lens (condenser lens) on an incidence plane and forms an object image (finder image) on an exit plane. Reference numeral **10** denotes a pentaprism used to deflect a finder optical path, and correct an object image formed on the exit plane of the focus plate **9** into an erect image. Reference numerals **11**, **12** denote eyepieces. The finder optical system is an optical system that includes the focus plate **9**, the pentaprism **10**, and the eyepieces **11**, **12**.

Reference numeral **13** denotes an automatic exposure ("AE") sensor, which includes photodiodes each corresponding to each of multi-divided image pickup areas, and is configured to measure the brightness of the object image formed on the exit plane of the focus plate **9**.

Reference numeral **14** denotes a liquid crystal monitor (display unit) configured to display a captured image and a variety of types of image pickup information. The liquid crystal monitor **14** displays an image of the object captured by the image pickup element **6** at the live view mode time, and AF frames which can be settable and has been set by a MC **33** that serves as an AF frame setting unit, which will be described later.

FIG. **3** is a block diagram of a control system of the digital single-lens reflex camera.

Reference numeral **20** is a microprocessor (referred to as a "MPU" hereinafter) configured to control the camera body and the entire camera.

The MPU (controller) **20** provides focusing based on a (first) defocus amount of a focus detecting point obtained by the AF sensor **8** as the detector. The AF frame is set by the MC **33** as the frame setting unit, as described later.

The MPU **20** also calculates a (second) defocus amount of an AF frame by performing the phase difference AF and by calculating output signals for the focus detecting pixels of the AF frame. The MPU **20** sets a correcting value for correcting a defocus amount obtained from a next detection result of the AF sensor based on a difference between the first defocus amount and the second defocus amount or provides a warning display.

Reference numeral **21** denotes a memory controller configured to provide a variety of types of controls of image data. Reference numeral **22** denotes an EEPROM configured to store settings for a variety of types of controls and adjustment data, etc., and the settings for the variety of types of controls includes a setting of a correcting value used for focusing, which will be described later. The SDRAM **43**, which will be described later, may store the setting of the correction value used for focusing, which will be described later.

Reference numeral **23** denotes a lens control circuit for the lenses in the image pickup lens **3**, which is connected to the MPU **20** through the mount **2** and provides focusing (in-focus driving) of the focus lens **3***a* and drives the stop unit based on information, which will be described later.

Reference numeral **24** denotes a focus detecting circuit configured to control the accumulation and readout of the area sensor of the AF sensor **8**, and to output to the MPU **20** pixel information of each focus detecting point (or each focus detecting area frame). The MPU **20** performs a known phase difference AF for the pixel information of each focus detecting point, sends the detected focus information to the lens control circuit **23**, and provides focusing of the focus lens **3***a*. A series of this operation from focus detecting to in-focus driving will be referred to as an AF operation.

More specifically, an in-focus position is calculated from an image shift amount between two images formed by object light fluxes that pass two different areas that held the optical axis of the image pickup lens **3**. The light fluxes of these two images pass the main mirror **4**, are reflected by the sub-mirror **7**, and are guided to the AF sensor **8**. The MPU **20** reads out signals of these two images, calculated the image shift amount by performing a correlative operation for these signals, and converts the image shift amount into a defocus amount for each focus detecting point.

Reference numeral **25** denotes a photometric circuit configured to output a brightness signal from each area of the AE sensor **13** to the MPU **20**. The MPU performs an analog-to-

digital conversion for the brightness signal into photometric information of the object, calculates and sets image pickup exposure using the photometric information. A series of operations from obtaining this photometric information to setting image pickup exposure will be referred to as an AE operation hereinafter.

Reference numeral **26** denotes a motor driving circuit configured to control a motor (not illustrated) for driving the main mirror **4** and a motor (not illustrated) for charging the shutter **5**. Reference numeral **27** denotes a shutter driving circuit configured to control power supply to a coil (not illustrated) for opening and closing the shutter **5**. Reference numeral denotes a DC/DC converter configured to convert a voltage of the power source **29** into a voltage necessary for each circuit.

Reference numeral **30** denotes a release button configured to output signals of SW**1** and SW**2** to the MPU **20**. SW**1** is a switch configured to turn on by a first stroke (half-pressing) and to start the photometry and the AF operation. SW**2** is a switch configured to turn on by a second stroke (full pressing) and to start the exposure operation.

Reference numeral **31** denotes a mode button. When an electronic dial **32** and the MC **33** are operated after the mode button is operated, a variety of types of modes are changed in accordance with the input. When the button is again operated, the mode is set. These modes include an automatic setting mode of a correcting value, which will be described later with reference to FIG. **8**, and a learning function setting mode, which will be described later with reference to FIG. **9**.

Reference numeral **32** denotes an electronic dial configured to output an ON signal in accordance with the dial's rotating clicks to an up/down counter (not illustrated) in the MPU **20**, and the number is counted. In accordance with the counted value, a variety of types of numerical values, data, etc. are selected.

Reference numeral **33** denotes a multi-controller ("MC") that serves as an input unit used to select and set an AF frame (focus detecting frame) and a variety of types and modes displayed on the liquid crystal monitor **14** at the live view time. The MC **33** allows inputs in such eight directions as up and down, left and right, up and to the right, down and to the right, up and to the left, and down and to the left, and an input by pressing.

The MC **33** serves as a mode setting unit configured to set a live view mode. The MC **33** also serves as a frame setting unit configured to set an AF frame that is a target of a focus detection, to an arbitrary position in the image pickup area of the image pickup element **6**. In this embodiment, the AF frame is set to a size of **6** fields in the lateral direction and **6** fields in the longitudinal direction, and can be moved to an arbitrary position in the image pickup area in accordance with an input signal of the MC **33**. In an example, the AF frame is moved every one field unit.

Reference numeral **34** denotes a power button configured to power on and off the camera when operated. Reference numeral **35** denotes a reproduction button, which enables, when operated, an image recorded in the media **48**, which will be described later, to be displayed on the liquid crystal monitor **14**.

Reference numeral **40** is a CDS (corrected double sampling)/AGC (automatic gain control) circuit for sample holding and automatic gain control of an image signal output from the image pickup element **6**. Reference numeral **41** denotes an A/D converter configured to convert an analog output to a digital signal.

Reference numeral **42** denotes a TG (timing generator) configured to supply a driving signal to the image pickup element **6**, a sample-holding signal to the CDS/AGC circuit **40**, and a sample clock signal to the A/D converter **41**.

Reference numeral **43** denotes an SDRAM (memory) configured to temporarily record an image etc. digitalized by the A/D converter **41**. The SDRAM **43** can record output signals of focus detecting pixels of the entire region of the image pickup area of the image pickup element **6**. Alternatively, the SDRAM **43** calculates and records a defocus amount by performing a phase difference AF for the entire region of the image pickup area of the image pickup element **6**.

Reference numeral **44** denotes an image processing circuit configured to perform a Y/C (brightness signal/color difference signal separation, a white balance correction, and a γ correction for an image. Reference numeral **45** denotes an image compression/decompression circuit configured to compress an image in accordance with JPEG or another format or to decompress the compressed image. The memory controller **21** allows the image processing circuit **44** to process an image signal output from the image pickup element **6**, and obtains photometric information of the object.

Reference numeral **46** denotes a D/A converter configured to convert an image into an analog signal so as to display on the liquid crystal display **14** an image recorded in the SDRAM **43** or the media **48**, which will be described later. Reference numeral **47** denotes an I/F (interface) with the media **48** so as to store the image.

The image file has an application marker segment used to record Exif appendix information. The application marker segment has 0^{th} IFD used to record appendix information relating to a compressed (primary) image, Exif IFD used to record appendix information specific to Exif, and 1^{st} IFD used to record a thumbnail image.

Exif IFD has a value of Exif IFD ("VEIFD") that is actually used to record data, such as a defocus amount of each focus detecting area (focus detecting data) obtained by the image pickup plane phase difference AF. The defocus amount data starts with recording from an upper left focus detecting area (field) on an image pickup plane and ends with recording to a lower right focus detecting area on the image pickup plane. When recording of the column in the horizontal direction ends, a field of the next row in the perpendicular direction starts.

Raw image data is referred to as an image file of a RAW data format before an image signal output from the image pickup element **6** and digitalized by the A/D converter **41** receives a variety of types of processing including a Y/C (brightness signal/color difference signal separation, a white balance correction, a γ correction, and a compression process.

The image file in the RAW data format has fields for image appendix information recordable a variety of types of information in accordance with a tag format of the Exif format, thumbnail data, and RAW data holding output data for each focus detecting pixel. The image appendix information holds positional information of the focus detecting pixels indicative of where the focus detecting pixels are arranged in the image pickup element **6**.

First Embodiment

FIG. **4** illustrates an operational flow of the MPU **20** of the digital single-lens reflex camera, and "S" in FIG. **4** and subsequent figures stands for the step.

Initially, when the power button **34** becomes turned on, the MPU **20** confirms operations of each actuator and the image pickup element **6** (S**101**), detects initialization states of the memory contents and execution programs, and executes an image pickup preparation operation. Next, the MPU **20** performs a variety of types of settings (such as an image pickup

mode and a shutter speed) of the camera in response to a variety of types of button operations (S102).

Next, the MPU **20** waits for turning on of SW1 (S103), and performs a phase difference AF using the AF sensor (dedicated sensor) **8** when determining that SW1 has been turned on (S104). Next, the MPU **20** performs an AE operation using the AE sensor **13** (S105), and displays a position of the focus detecting point that is focused on the viewfinder (S106).

Next, the MPU **20** waits for turning on SW2 (S107), and performs normal image pickup when determining that SW2 has been turned on (S108). FIG. **5** is a normal image pickup routine.

Initially, the MPU **20** controls a mirror driving motor (not illustrated) through the motor driving circuit **26**, and retreats (or moves up) the main mirror **4** and the sub-mirror **7** from the image pickup optical path, as illustrated in FIG. **2** (S111).

Next, the MPU **20** allows the lens control circuit **23** to drive the stop (not illustrated) in the image pickup lens **3** in accordance with the image pickup exposure calculated based on the AE result (S112), and allows the shutter driving circuit **27** to open and close the shutter **5** (S113).

Next, the MPU **20** allows the memory controller to read out and temporarily store in the SDRAM **43** the image signal derived from the light received by the image pickup element **6** (S114). This temporarily stored data is the image pickup data.

Next, the MPU **20** interpolates the defective pixels of the image signal read out by the memory controller **21** (S115). Since the focus detecting pixels have no RGB color information and correspond to defective pixels, the image signal is generated through interpolations using information of the surrounding image pickup pixels. A defective-pixels interpolated image is made by interpolating the defective pixels from the generated image signal and the original image signal, and temporarily stored in the SDRAM **43**.

Next, the MPU **20** allows the memory controller **21** to prepare a thumbnail image based on the defective-pixels interpolated image and to temporarily store it in the SDRAM **43** (S116). Next, the MPU **20** determines which of JPEG and RAW is selected for the recorded image quality of the captured image (S117), and executes the focus detecting pixel (AF pixel) signal recording routine (S118) when JPEG is selected.

FIG. **6** is an AF pixel signal recording routine of **5118**.

Initially, the MPU **20** reads out each focus detecting pixel contained in each focus detecting area using the image signal temporarily stored in SDRAM **43** and the memory controller **21** (S131). Next, the MPU **20** allows the memory controller **21** to add the focus detecting pixels in each section, and obtains the AF pixel signal of each section (S132).

Next, the MPU **20** generates signals of two images for correlative operation based on the AF pixel signal, for each focus detecting area (S133). The focus detecting area is the same area as one field, and 1350 pairs of signals are generated for the entire image pickup area in this embodiment.

Next, the MPU **20** performs a correlative operation for the obtained two images, and calculates a relative positional shift amount between the two images (S134). Next, the MPU **20** operates a defocus amount (S135). Next, the MPU **20** allows the memory controller **21** to temporarily store the operated defocus amount in the SDRAM **43** (S136). The defocus amount has data of 1350 focus detecting areas.

Turning back to FIG. **5**, the MPU **20** allows the image processing circuit **44** to perform image processing, such as a white balance correction, a γ correction, and an edge enhancement, for the defective-pixels interpolated image, and allows the image compression/decompression circuit **45** to compress the resultant image in accordance with the JPEG format. In addition, the MPU **20** allows the memory controller **21** to record the data in the image compression data unit. Moreover, the MPU **20** stores a thumbnail image in the 1st IFD and defocus amount data in the VEIFD. Furthermore, the MPU **20** stores a variety of types of settings of the camera (such as a shutter speed, an aperture value, and a lens focal length) in accordance with the Exif rule, and prepares JPEG files of an image and a variety of types of data.

On the other hand, when the MPU **20** determines that RAW is selected (S117), the MPU **20** allows the memory controller **21** to record in the RAW data the image signal temporarily stored in the SDRAM **43**. In addition, the MPU **20** records the positional information of the focus detecting pixels and a variety of types of setting of the camera in the image appendix information and the thumbnail image in the thumbnail data, thereby making RAW files of an image and a variety of types of data (S120).

Next, the MPU **20** records the JPEG or RAW image file in the media **48** (S121). Next, the MPU **20** controls a mirror driving motor (not illustrated) via the motor driving circuit **26**, and moves down the main mirror **4** and the sub-mirror **7** that have been retreated from the image pickup optical path to observation positions to reflect and guide the image pickup light flux to the viewfinder (S122). Next, the MPU **20** controls electrifications to the charging motor (not illustrated) through the motor driving circuit **26**, and charges the shutter **5** (S123).

Next, turning back to FIG. **4**, the MPU **20** executes the defocus correcting value setting routine (S109).

FIG. **7** illustrates a flow of a defocus correcting value setting routine of S109.

Initially, the MPU **20** reads out a defocus amount of each focus detecting point from the image signal temporarily recorded in the SDRAM **43** through the memory controller **21** (S141). In addition, the MPU **20** confirms the focus detecting point for which the in-focus operation to be corrected is performed by the memory controller **21** (S142).

Next, the MPU **20** sets a correcting value for lowering or removing a defocus amount of the focus detecting point of **5142** in the EEPROM **22** (S143). Next, the MPU **20** sends the correcting value to the lens control circuit **23** so that the correcting value can be reflected for the next lens driving control and used for in-focus driving of the focus lens unit of the image pickup lens **3** (S144).

Next, turning back to FIG. **4**, the MPU **20** determines whether the camera is powered off by the OFF manipulation of the power button **34**. When the camera is not powered off, the MPU **20** returns the flow to S102. When the camera is powered off, the MPU **20** ends the operation (S110).

In this embodiment, after a defocus amount is detected using the AF sensor **8** (S104), a defocus amount of the focus detecting point read out of the actually captured image signal (captured image) is calculated, and the defocus amount using the AF sensor is corrected based on the read data.

Only focusing using the AF sensor **8** may cause defocus due to the scattering secondary imaging focus detecting precision and scattering driving precision (such as stopping precision) of the image pickup lens at the focusing time. This embodiment can precisely set a correcting value of a defocus amount, and reflect a correcting value in the next lens driving control. As a result, the in-focus precision of the phase difference AF on the secondary imaging plane can be improved.

While the image pickup plane phase difference AF data recorded in the JPEG file is a defocus amount of each focus detecting area in this embodiment, a defocus-amount calculating range is not limited to the focus detecting area and may be set every section. The image pickup plane phase difference

AF data is not limited to the defocus amount but may be distance measurement data, such as a distance from the camera to an object which is calculated based on the information of the image pickup lens **3** and the defocus amount. In addition, since the focus detecting pixel data is recorded in the RAW data, the image pickup plane phase difference AF data is not recorded in the image appendix information but may be recorded similar to the JPEG file.

Second Embodiment

This embodiment uses a defocus correcting value setting routine illustrated in FIG. **8** instead of that illustrated in FIGS. **7**. S**141** and S**142** are similar to those illustrated in FIG. **7**, and the MPU **20** determines whether the defocus correction is automatically set after S**142** (S**145**).

When the defocus correction is not automatically set (N of S**145**), a manual correction-value input mode is set. The MPU **20** displays the focus detecting points confirmed in S**142** (S**146**), displays a correcting value obtained in S**141** (S**147**), and allows a photographer to input the correcting value (S**148**).

After S**148** or when the MPU **20** determines that defocus correction is automatically set (Y of S**145**), the MPU **20** performs S**143** and S**144** illustrated in FIG. **7**, and thereafter moves to S**110** illustrated in FIG. **4**.

This embodiment enables a photographer to manually input a correcting value in S**146** to S**148**. Therefore, this embodiment can improve the in-focus precision by setting a correcting value individually suitable for the in-focus state which is considered appropriate by the photographer.

Third Embodiment

This embodiment uses a defocus correcting value setting routine illustrated in FIG. **9** instead of that illustrated in FIGS. **7**. S**141** and S**142** are similar to those steps illustrated in FIG. **7**, and the MPU **20** determines whether a learning function is set after S**142** (S**149**).

When the learning function is set (Y of S**149**), a correcting value input mode using the learning function is set and the MPU **20** sets the learning number (S**150**). When the learning number N is set, the MPU **20** learns defocus amounts N times. When N defocus amounts are learned, the learning number is reset. The post-reset number starts with "once." When the learning number is set to "0 times," the defocus amounts are continuously learned.

Next, the MPU **20** stores the set number of defocus amounts (S**151**), and then resets the stored defocus amount. When the number is reset and the learning number is set to "0 times," the defocus amounts are continuously stored. In this case, an upper limit of the storing number of the defocus amount may be set in accordance with the storage capacity of the SDRAM **43**.

Next, the MPU **20** calculates a correcting value of the defocus data through averaging (S**152**). For example, when the learning number is set to three times, rather than calculating a correcting value after the defocus amount data is stored three times, a correcting value is obtained at the first time, calculated based on an average of the two defocus amounts at the second time, and calculated based on an average of the three defocus amounts at the third time. Even when the learning number is reset, the calculated correcting value is preserved. In addition, a plurality of correcting values may be held.

When the learning number is set to "0 times," the defocus amount data are continuously stored in S**151** and the correcting values are continuously calculated in S**152**. In this case, a correcting value may be calculated after an upper limit of the storing number of defocus amounts is set in accordance with the storage capacity of the SDRAM **43**.

After S**152** or when the MPU **20** determines that the learning function is not automatically set (N of S**149**), the MPU **20** performs S**143** and S**144** illustrated in FIG. **7** and thereafter moves to S**110** illustrated in FIG. **4**.

This embodiment calculates a correcting value based on an average of a plurality of defocus amounts through S**150** to S**152**, is unlikely to set a correcting value that happens to contain a large error, and improves the in-focus precision.

Fourth Embodiment

This embodiment uses a defocus correcting value setting routine illustrated in FIG. **10** instead of that illustrated in FIGS. **7**. S**141** and S**142** are similar to those illustrated in FIG. **7**, and the MPU **20** determines whether an exchange lens is attached after S**142** (S**153**).

When the MPU **20** determines that the exchange lens has been attached (Y of S**153**), the MPU **20** identifies lens specific information of the exchange lens (S**154**). The lens specific information contains a lens ID used to identify a lens type, a lens open F value, etc., and the lens control circuit **23** and the MPU **20** can identify the lens specific information by communicating with the image pickup lens **3**.

Next, the MPU **20** calculates a correcting value of the defocus amount (S**155**), and stores a correcting value for lens specific information in the EEPROM **22** (S**156**). Thereafter, the MPU **20** performs **5143** and **5144** illustrated in FIG. **7**, and thereafter moves to **5110** illustrated in FIG. **4**.

On the other hand, when the MPU **20** determines that the exchange lens is not attached (N of S**153**), the MPU **20** warns the photographer of the non-attachment of the lens (S**157**) and thereafter moves to S**110** of FIG. **4**.

According to this embodiment, the MPU **20** sets a correcting value for the lens specific information, and can improve the in-focus precision without using an erroneous correcting value for the image pickup lens.

Fifth Embodiment

This embodiment uses a defocus correcting value setting routine illustrated in FIG. **11** instead of that illustrated in FIG. **7**.

Initially, the MPU **20** detects that the camera is switched from the image pickup mode to the image reproducing mode after the reproduction button **35** is turned on (S**161**), and allows the memory controller **21** to display on the liquid crystal monitor **14** an image file (captured image) recorded in the media **48** (S**162**). Here, an image file is recorded as a JPEG file in the media **48**.

Next, the MPU **20** superimposes the AF frame on the captured image, which was used for the focus detection by the AF sensor **8** at the image pickup time (S**163**). The positional information of the AF frame is recorded in the VEIFD, and read out by the memory controller **21**.

Next, the MPU **20** displays defocus information in response to pressing of the MC (S**164**), and deletes the AF frame from the liquid crystal monitor **14** (S**165**).

Next, the MPU **20** displays a focus detecting point (or area) (S**166**). Since each focus detecting area corresponds to one field area and a defocus amount for each field is recorded in a JPEG file in this embodiment, a focus detecting point is displayed on the liquid display monitor **14** every one field. An initially displayed position of the focus detecting point is a position having the smallest defocus amount.

Next, the MPU **20** allows the memory controller **21** to read out a defocus amount at a position of the focus detecting point from the data recording area in the JPEG file, and to display it on the liquid crystal monitor **14** (S**167**). FIG. **12** illustrates this state, where a defocus amount of the focus detecting point is displayed as "−5 mm" at the lower right portion of the liquid crystal monitor **14**.

Next, the MPU **20** determines whether an input in one of the eight directions is made using the MC **33** (S**168**).

When the MPU **20** determines that the MC **33** has been operated (Y of S**168**), the MPU **20** moves the focus detecting point in accordance with the manipulation of the MC **33** (S**171**). Therefore, the MC **33** serves as a selector configured to select a second focus detecting point different from the first focus detecting point.

Next, the MPU **20** allows the memory controller **21** to read out a defocus amount at a position of the moved focus detecting point from the data recording area in the JPEG file, and to display it instead of the pre-movement defocus amount (S**172**).

Next, the MPU **20** sets a correcting value used to reduce or remove a defocus amount (S**173**). The correcting value is set so as to correct the defocus amount by pressing the MC **33** when the MPU **20** moves the focus detecting point in accordance with a manipulation of the MC **33** and displays the defocus amount of the focus detecting point. When the MC **33** is operated in the up-and-down direction in this state, a defocus amount can be increased or decreased. A correcting value having a changed value for the defocus amount is set by again pressing the MC **33** after the correcting value is increased or decreased.

On the other hand, when the MPU **20** determines that the MC **33** is not manipulated (N of S**168**), the MPU **20** displays the correcting value of the defocus amount on the liquid crystal monitor **14** (S**169**). Next, the MPU **20** determines that an operational button, such as the release button **30** and the power button **34**, which is not used in the reproduction mode is operated (S**170**), the MPU **20** ends the reproduction mode.

According to this embodiment, a photographer can confirm image pickup plane phase difference AF data at an arbitrary position in the captured image recorded in the image file when the image is reproduced. In addition, the photographer can change a position of the focus detecting point, obtain a defocus amount at that position, and set a correcting value. Therefore, the photographer can set a correcting value suitable for a focus detecting point which the photographer would like to stress, and improve the correcting value. An MC **33** operating method for changing a value of a defocus amount is not limited.

Sixth Embodiment

This embodiment uses FIG. **15** instead of FIG. **4**. In FIG. **13**, the flow from S**101** to S**106** is similar to that of FIG. **4**, and the MPU **20** again detects a defocus amount using the AF sensor **8** after S**106** (S**175**).

Next, the MPU **20** records a defocus amount for each focus detecting point in the memory controller **21** (S**176**). The MPU **20** performs S**107** and S**108** after S**176**, and then executes a defocus correcting value setting routine (S**177**).

FIG. **14** is a flow of a defocus correcting value setting routine of S**177**.

Initially, the MPU **20** allows the memory controller **21** to read out the defocus amount obtained in S**175** (S**181**). Next, the MPU **20** allows the memory controller **21** to read out a defocus amount included in each focus detecting area (S**182**).

Next, the MPU **20** allows the memory controller **21** to confirm the focus detecting point with which the in-focus action has been performed (S**183**).

Next, the MPU **20** calculates a defocus amount based on a difference between the defocus amount of S**181** and the defocus amount of S**182** (S**184**). This operation calculates a difference between a defocus amount obtained by the focus detection using the secondary imaging phase difference and the AF sensor **8** and a defocus amount obtained from the actually captured image signal.

Next, the S**143** and S**144** are performed, and the flow is then moved to S**110** of S**13**.

This embodiment is different from FIG. **4** in that the focus detection using the AF sensor **8** is again performed in S**175** so as to detect a precise focus state of the secondary imaging focus detection when the AF operation ends.

Only focusing of S**104** may cause defocus due to the scattering secondary imaging focus detecting precision and the scattering driving precision of the image pickup lens at the focusing time. This embodiment can precisely find a difference between the defocus amounts from the captured image and a correcting value of a defocus amount by again performing a focus detection using the AF sensor **8** in S**175** so as to precisely detect the secondary imaging focus state. As a result, this embodiment can improve the in-focus precision.

Seventh Embodiment

This embodiment uses FIG. **15** instead of FIG. **4**. FIG. **15** provides a warning determination routine (S**178**) instead of S**109** illustrated in FIG. **4**. FIG. **16** is a warning determination routine of S**178**, and the flow of S**141** and S**142** is similar to that illustrated in FIG. **7**.

After S**142**, the MPU **20** determines whether the defocus amount of S**142** falls within a threshold (S**185**). This threshold is set so as to secure a practically permissible range in which an image can be considered in focus, or a defocus range (threshold range) within a circle of confusion.

When the MPU **20** determines that the defocus amount is within the threshold (Y of S**185**), the MPU **20** performs S**143** and S**144** and moves the flow to S**110** illustrated in FIG. **15**.

On the other hand, when the MPU **20** determines that the defocus amount is not within the threshold (N of S**185**), the MPU **20** provides a warning display on the liquid crystal monitor **14** so as to inform the photographer of a large defocus amount as illustrated in FIG. **17** (S**186**). In FIG. **17**, the lower right portion of the liquid crystal monitor **14** illustrates that an image was taken when a defocus amount is larger than the threshold and the main object was out of focus.

The MPU **20** moves to S**110** illustrated in FIG. **15** when any operational member is operated (S**187**).

This embodiment provides a warning display when a difference is equal to or larger than a threshold between a defocus amount obtained from the detection result of the AF sensor **8** and a defocus amount obtained from the detection result of the focus detecting pixels, and improves the in-focus precision by informing the photographer of defocus.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2010-105596, filed Apr. 30, 2010 which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An image pickup apparatus comprising:

a first image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, wherein the first image pickup element is configured to be located on a secondary imaging plane;

a second image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, wherein the second image pickup element is configured to be located

on a primary imaging plane, wherein the second pickup element is configured to be able to output signal for recording image;

a first detector configured to detect a defocus amount related to a phase difference between two images of the object from the first image pickup element;

a second detector configured to detect a defocus amount based on a phase difference for two images of the object recorded from the second image pickup element; and

a controller configured to provide focusing based on a defocus amount obtained from a detection result of the first detector, and set a correcting value used to correct a defocus amount obtained from a detection result of the first detector so that a difference can be reduced between the defocus amount obtained from the detection result of the first detector and a defocus amount obtained from the detection result of the second detector, wherein the correcting value is acquired from information according to the defocus amount detected by the second detector by using signal for recording image.

2. A focusing method used for an image pickup apparatus, the image pickup apparatus including a first image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, wherein the first image pickup element is configured to be located on a secondary imaging plane, a second image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, wherein the second image pickup element is configured to be located on a primary imaging plane, wherein the second pickup element is configured to be able to output signal for recording image, a first detector configured to detect a defocus amount related to a phase difference between two images of the object from the first image pickup element, and a second detector configured to detect a defocus amount based on a phase difference for two images of the object recorded from the second image pickup element, and the image pickup apparatus being configured to provide focusing based on a defocus amount obtained from a detection result of the first detector, said focusing method comprising setting a correcting value used to correct a defocus amount obtained from a detection result of the first detector so that a difference can be reduced between the defocus amount obtained from the detection result of the first detector and a defocus amount obtained from the detection result of the second detector wherein the correcting value is acquired from information according to the defocus amount detected by the second detector by using signal for recording image.

3. The image pickup apparatus according to claim **1**, wherein the second image pickup element is configured to be able to output signal for live view image.

4. The image pickup apparatus according to claim **1**, wherein the second image pickup element is configured to receive light that passes part of an exit pupil of the image pickup lens.

5. The image pickup apparatus according to claim **1**, wherein the second detector is configured to detect a defocus amount related to a phase difference between two images of the object from the second image pickup element.

6. The image pickup apparatus according to claim **1**, wherein the second image pickup element is configured to include focus detecting pixels for a first focus detecting point of a captured image of the object that has been captured.

7. The image pickup apparatus according to claim **1**, the second image pickup element is an image pickup element that includes a plurality of image pickup pixels each configured to generate an image of an object by performing a photoelectric conversion for light from an image pickup lens, and a plurality of focus detecting pixels each configured to receive light that passes part of an exit pupil of the image pickup lens.

* * * * *